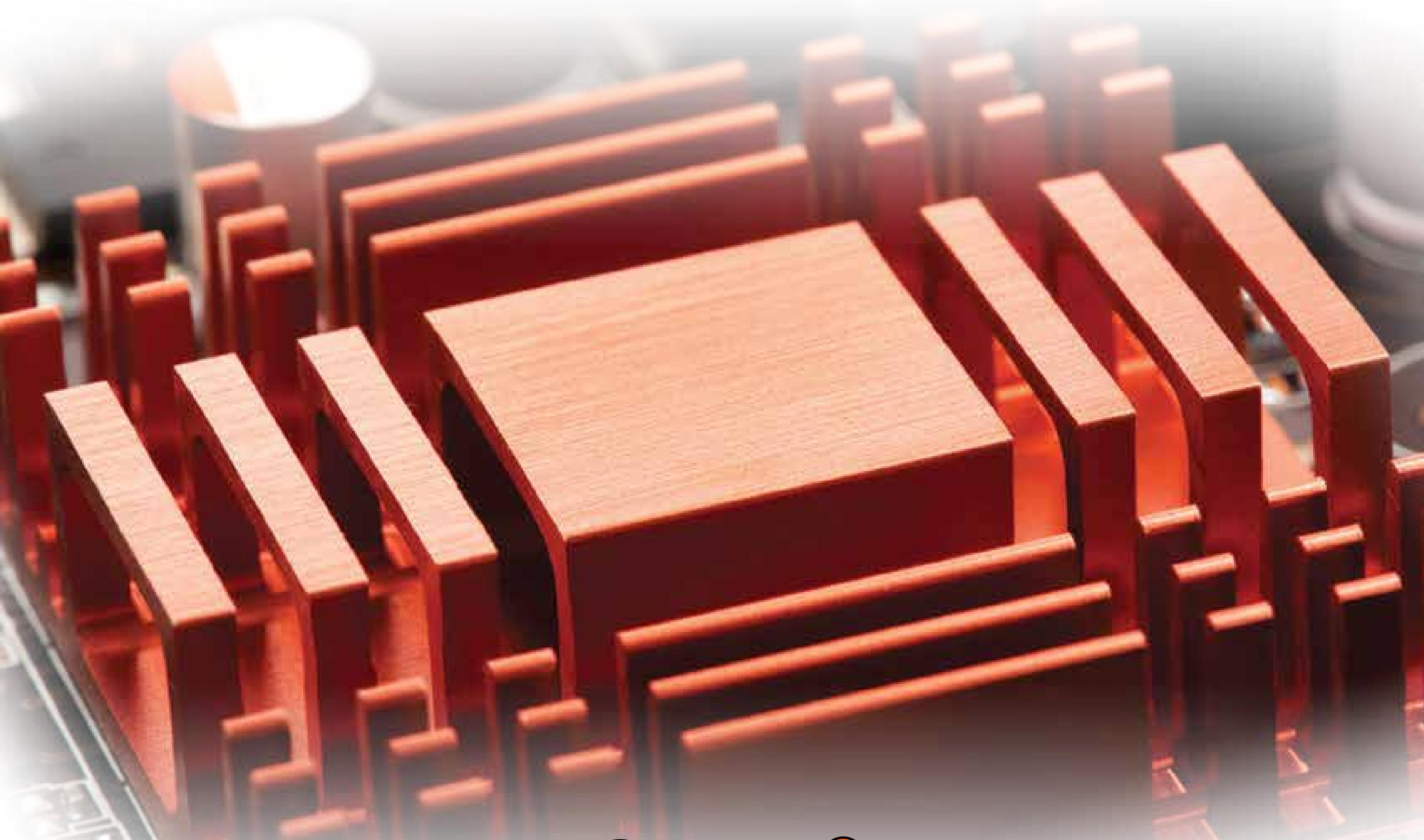
Optimizing Thermal Management



...with EPO-TEK®
Thermally Conductive Adhesives

EPOXY TECHNOLOGY

Optimizing Thermal Management ...

The best way to improve Thermal Management in Microelectronics Design starts with a better understanding of Thermally Conductive Adhesives and Thermal Conductivity Measurement Methods.

What are Thermally Conductive Adhesives, *and Where are They Used?*

Thermally Conductive Adhesives contain a variety of fillers and filler loadings which are formulated to transfer heat. Within this classification of products, is a special sub category called Thermal Interface Material (TIM) that provide both high bond strength across an interface, as well as low thermal resistance.

Typical applications include: heat sink mounting, die bonding, coil potting and electronics encapsulation.

Epoxy resins in general are thermally insulative, with typical conductivity (ThK) values ranging from 0.1-0.2 W/mK. Special filler systems can be added to facilitate heat to flow more quickly through the resin matrix.

Depending on the type of filler systems used, cured TCAs can have a resulting **bulk Thermal Conductivity** from 0.5 W/mK to upwards of 35 W/mK; second only to soldering in ultimate heat transfer capabilities. Using TCAs with high thermal performance allows for substantial heat transfer and improved device performance.

What's the Difference between bulk *Thermal Conductivity* and *Thermal Resistance*?

Thermal Conductivity

Thermal Conductivity is a fundamental material property that is used to characterize heat transfer. It is equal to the rate of heat transferred through a known sample area, when the sample's opposite face is subjected to an applied heat gradient.

Although **bulk** thermal conductivity does give some indication of the ability of a product to transfer heat, it is ***only*** one part of the data needed to make the best adhesive product selection for your specific application.

Typical units are W/mK, and is measured using Laser Flash Diffusivity. Thermal conductivity is an intrinsic material property and does ***NOT*** take into account minimum bond line thickness or interfacial resistance between the adhesive and bonded substrates.

Thermal Resistance

Thermal Resistance determines the effectiveness of an adhesive to draw heat away from sensitive components. There are a number of factors to take into consideration when measuring Thermal Resistance, that are **NOT** related to bulk Thermal Conductivity measurements.

Thermal Resistance is device and geometry dependent and, once calculated, gives more specific and reliable data.

There **is** a direct relationship between Thermal Conductivity and Thermal Resistance that can be estimated using bulk Thermal Conductivity data using the following equation:

$$R = l/kA$$

l = bond line thickness
k = thermal conductivity
A = effective surface contact

Thermal Interface Material (TIM)

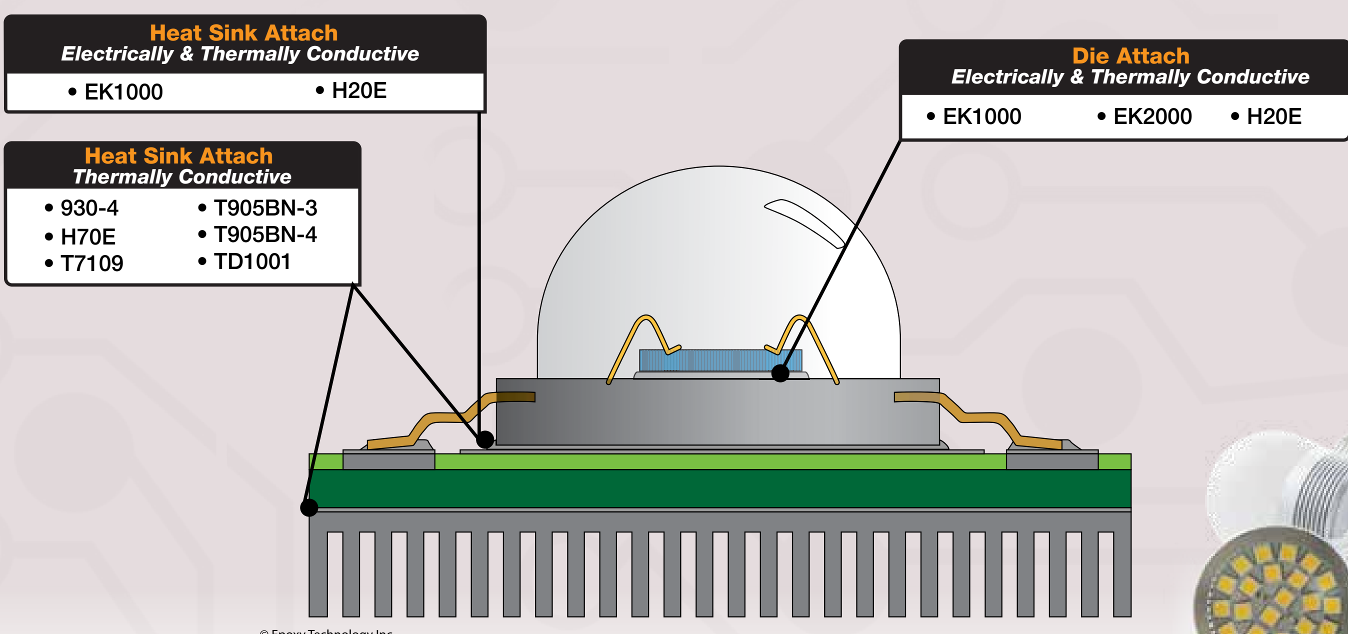
Highest Thermal Conductivity & Electrically Conductive Adhesive

The majority of Electrically Conductive Adhesives (ECAs) are formulated with silver fillers. This type of product allows for ***both*** high electrical conductivity ***and*** superior thermal conductivity. Silver is second only to diamonds in terms of a thermal conductivity comparison.

Silver-filled epoxies are able to achieve thermal conductivity values of >10 W/mK and higher, depending on the cure conditions used and the selected ECA. Applications that do not have restrictions on electrical conductivity can significantly benefit from this type of TCA.

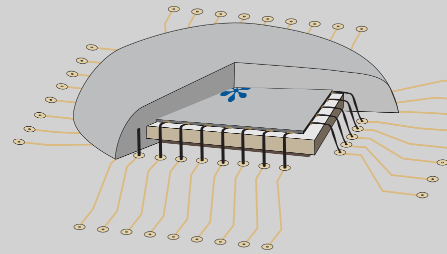
High Thermal Conductivity, Electrically Conductive

EPO-TEK Product	Cure Schedule	Thermal Conductivity (W/mK)
EK1000 (single component PMF sringe) EK2000 (two component) Most advanced ECA formulation	150°C/1 hour	12.6
	150°C/1 hour + 200°C/1 hour	26.3
	125°C/2.5 hours + 150°C/36 min + 200°C/15 min	35.5
EK1000-1 Newest version of EK1000, designed for a longer dry time	150°C/1 hour	12.1
	150°C/1 hour + 200°C/1 hour	22.7
H20E Proven reliability 40+ years in use	150°C/1 hour	2.5



-TEK® Thermally Conductive Adhesives

High Thermal Conductivity & Electrically Insulating Adhesives



In applications where electrical conductivity is ***not*** permitted, it is still possible to obtain improved thermal performance using epoxies that are thermally conductive only. These epoxies can achieve thermal conductivity values ranging from 1-5 W/mK.

The trade-off in using these types of materials is that some tend to have very large filler particles, combined with a high filler loading. Larger particles help to maintain conductivity by decreasing the number of particles needed to bridge a bond line; therefore, reducing insulating particle to particle transitions. This, however, can also cause the material to have very high viscosity; making them hard to dispense and difficult to get into tight spaces.

This type of adhesive a great choice for ***heat sinking*** or ***thermal potting.***

High Thermal Conductivity, Electrically Insulating

EPO-TEK Product	Cure Schedule	Thermal Conductivity (W/mK)
930	150°C/ 1 hour	4.57
930-4	150°C/ 1 hour	1.67
T7109	150°C/ 1 hour	1.5
T7109-19	80°C/ 2 hours	1.3
T905BN-3	80°C/ 2 hours	2.02

Standard Thermal Conductivity & Electrically Insulating Adhesives

Most standard thermally conductive adhesives have a thermal conductivity between 0.5 and 1 W/mK. While not much higher than an unfilled epoxy, it can provide adequate cooling in many applications. An advantage is that these materials tend to be easier to use, due to their lower viscosities and are easily dispensed or printed.

These materials are an excellent choice for anything from ***die attach*** to ***thermal potting***.

Standard Thermal Conductivity, Electrically Insulating

EPO-TEK Product	Cure Schedule	Thermal Conductivity (W/mK)
H70E	150°C/1 hour	0.9
H77	150°C/1 hour	0.66
T7110	80°C/2 hours	1.0

...by Understanding and Measuring Thermal Resistance in a Design

Experiment: **Determine Best Thermal Management for a Specific Part Design**

Thermal Data - *prior* to bonding

Product	% Filler (by weight)	Mean Filler Size (um)	Viscosity (cPs)	Data Sheet ThK (W/mK)
Adhesive "A"	68	300	250,000	4
Adhesive "B"	30	3	17,000	1.5

Bond Line = 3.0mil   Bond area = 100µm

Actual Device Measurement

Thermal Data - *after* bonding

Product	Data Sheet ThK (W/mK)	Expected Thermal Resistance (C/W)	*Actual Thermal Resistance (C/W)
Adhesive "A"	4	0.19	2
Adhesive "B"	1.5	0.5	0.7

* Remember that the lower the Thermal Resistance, the better the overall thermal performance of the material

Results

- **Adhesive "A" with the higher bulk ThK, was outperformed by a lower ThK material, Adhesive "B".**
- **As shown in the above data tables, using *Thermal Conductivity* (ThK) data alone can be very misleading.**
- **It is the measured *Thermal Resistance* of the final product that shows overall thermal performance.**

Why was Adhesive "A" outperformed?

Bond Line Thickness (BLT)

Adhesive "A" uses a larger particle size filler than Adhesive "B". Although the large particle size helps to achieve a higher bulk thermal conductivity value (ThK), it limits the minimum bond line thickness achievable. This is important as thermal resistance is directly proportional to the thickness of the bond line.

Potential for Void Formation/Poor Wetting of Substrate

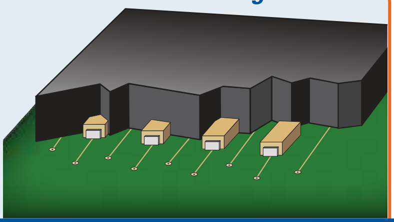
To allow for the most efficient heat dissipation, any potential air voids along the bonding interface should be minimized. In addition, higher filler loaded systems, combined with a high viscosity can result in poor chemical wetting of a substrate, causing an increase in thermal resistance. A higher viscosity material will not wet out the substrate as well as a lower viscosity material. This combination of air entrapment with poor chemical wetting of the substrate causes higher resistance at the interface.

Note:

In ***Potting*** applications, thermally conductive adhesives with large particle sizes will **not** have the same outcome as the "bond line" example above. It is dependent on how thick the material be can applied.

Choosing a large particle sized adhesive for potting is an effective method for adequate thermal management.

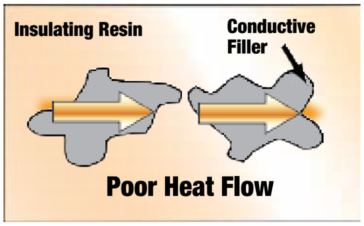
Potting Material



The Effect of Cure and Shrinkage on Heat Flow

Low Shrinkage

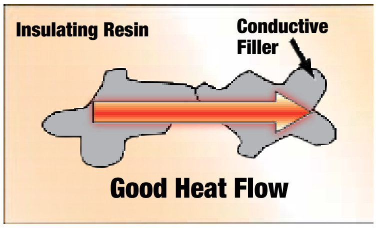
Minimal Particle Overlap/Contact



High Resistance/
Low Thermal Conductivity

Optimal Shrinkage

Optimal Shrinkage/Good Contact

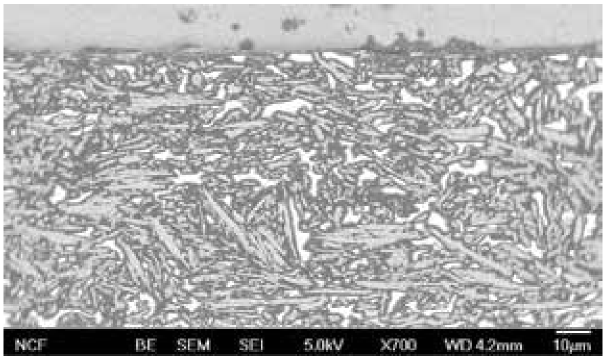


Low Resistance/
High Thermal Conductivity

Impact of Cure Conditions:

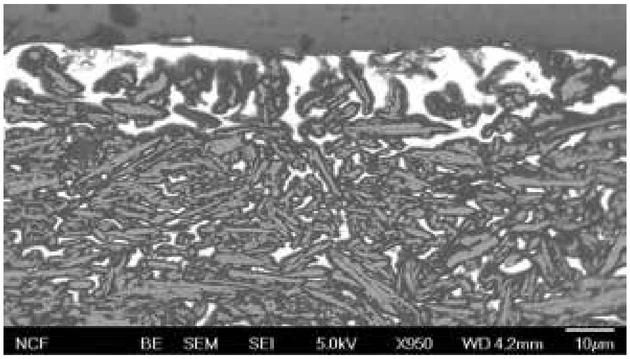
- **Too low** of a cure temperature will result in slow cure and low crosslink density.
- **Too high** of a cure temperature can produce high exotherms causing expansion rather than shrinkage.
- **Proper** cure conditions are dependent on the chemistry of the adhesives.

Good Thermal Distribution



Adhesive with ***good*** distribution at the interface

Poor Thermal Distribution



Adhesive with ***poor*** distribution at the interface

Above SEM photos show optimal shrinkage (good thermal distribution) & low shrinkage (poor thermal distribution) in an actual bond line.

Contact our ***Adhesive Experts*** for technical discussions and assistance in finding the best adhesive solution for your bonding challenges at:

+1.978.667.3805 or **techserv@epotek.com**

For ordering, please contact us at:

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